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Effects of all-terrain vehicle traffic on tundra terrain near Anaktuvuk Pass, Alaska

Charles H. Racine and Lawrence A. Johnson

Prepared for
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Six- and eight-wheel, light-weight all-terrain vehicles (ATVs) (mainly the Argo with low-pressure, low-ribbed tires) are currently used in the Anaktuvuk Pass, Alaska, area for summer subsistence travel from the village into several Brooks Range valleys. The environmental effects of summer ATV use are poorly understood. During the summers of 1985 and 1986, terrain disturbance at 31 sites representing trails over dry, moist and wet tundra was evaluated by rating the levels of soil exposure, vegetation destruction and microtopographic depression (ruts). Surface and frozen layer profiles across selected trail sites were also obtained, and trail visibility from the air and ground was rated. The levels of trail disturbance vary between valleys and generally decrease with distance from the village of Anaktuvuk Pass. Trails over dry tundra showed low to moderate terrain disturbance; tne hard substrate and shallow organic cover resulted in low surface depression and low exposure of mineral soil. However, vegetation disturbance was often high, particularly to lichens and taller shrubs. These trails were generally of low visibility except where light-colored lichens were removed. Terrain disturbance on trails over moist tundra varied from low to high. As long as cottongrass tussocks remained intact and supported vehicle weight, terrain disturbance

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was low; once tussocks were destroyed, deep ruts developed quickly, followed by trail abandonment and formation of a new parallel track. Thawing increased under the highly disturbed trails, but thermokarst formation was infrequent because the ice content of the soils in the Anaktuvuk Pass area is generally low. Wet tundra trail sites showed moderate to high terrain disturbance with low vegetation disturbance but high microtopographic changes. On wet tundra, drivers often move to an adjacent new trail following only a few passes, reducing the disturbance in one track. Visibility was generally high because of standing water in the tracks and the presence of several parallel tracks.

PREFACE

This report was prepared by Dr. Charles H. Racine, Biologist, and Lawrence A. Johnson, former Biologist, Geochemical Sciences Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory. Funding was provided by the Department of the Interior, Bureau of Indian Affairs, under Agency Order No. EOOC14202832, *Assist Indian People to Inventory, Conserve, Develop, and Use Their Natural Resources.* The report was reviewed by David Scott of the Bureau of Indian Affairs and Antonio Palazzo of CRREL.

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Effects of All-Terrain Vehicle Traffic on Tundra Terrain Near Anaktuvuk Pass, Alaska

CHARLES H. RACINE
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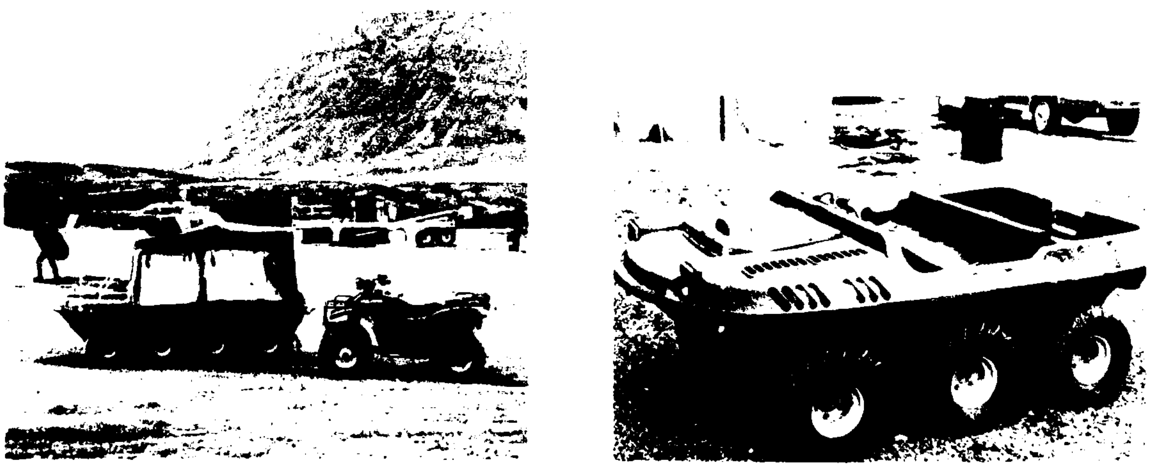
In northern Alaska during the past ten years, there has been a dramatic increase in the personal ownership and use of small tracked or wheeled amphibious all-terrain vehicles (ATVs) (Fig. 1) for summer off-road hunting, fishing and recreation. This increase was caused by the need for improved personal mobility and transportation due to changing economic and cultural conditions, particularly the need for access to subsistence harvest areas and the introduction of the relatively inexpensive three-wheel "all-terrain cycle" (ATC) in 1970. Similar four-wheel vehicles have appeared over the past five years. Larger six-wheel, eight-wheel or tracked ATVs have been produced since 1960; these are considerably more expensive than the ATC, but they transport much larger loads (Table 1).

These changes in the summer use of ATVs in the north are in some ways analogous to the snowmobile revolution among northern people (Hall 1971). Snowmobiles generally produce minimal environmental impacts where there is sufficient snow depth (Keddy et al. 1979), but the en-

Table 1. Types and characteristics of off-road vehicles (ORVs) used or tested on arctic permafrost terrain.

Vehicle type	*Weight (kg)*	*Ground pressure (kg/cm²)*	*(psi)*	*Tires or tracks*
Large ORVs (Industrial use)				
Caterpillar (D-7)	15,800	0.70	10.5	Steel tracks
Rolligon (Catco)	11,700	0.35	5.0	8 wheels, smooth
Rolligon (Houston)	6,800	0.25	3.5	6 wheels, ribbed
SUSV (BV206)	4,620	0.18	2.5	Rubber tracks
Medium ORVs (Personal or industrial use)				
Nodwell (FN-10)	2,250	0.10	1.4	Tracks
Weasel (M-29)	1,200	0.07	1.0	Tracks
Bombardier "Bombi"	1,100	0.05	1.3	Tracks
Small ORVs (Personal use)				
Coot	500–600	0.70	10.0	4 tires
Sidewinder–Hustler	400	0.70	0.0	6 tires
Argo	350–400	0.18	2.5	6–8 tires
Honcho	175	0.70	10.0	4 tires
Honda ATC	90–150	0.10	1.5	3–4 knobby tires



a. Eight-wheel Argo (left) and four-wheel all-terrain cycle (right).

b. Argo six-wheel ATV. Note the two types of tires.

Figure 1. All-terrain vehicles in use at Anaktuvuk Pass, Alaska.

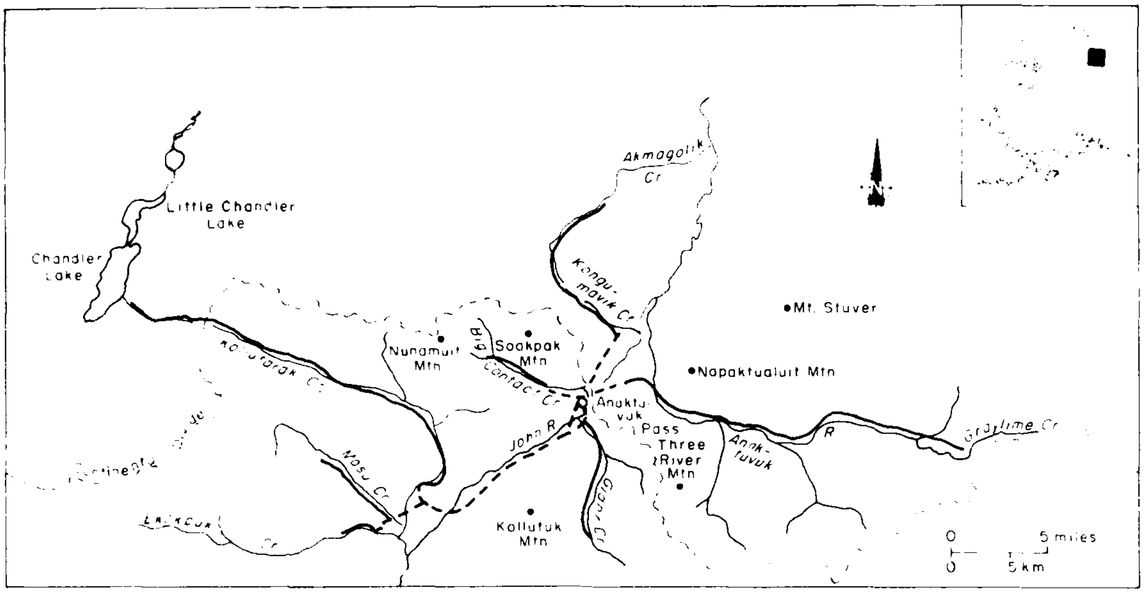


Figure 2. Map of the Anaktuvuk Pass, Alaska, area showing the ATV travel routes. The dashed lines are access trails from the village to the valley trails.

vironmental impacts of summer ATV use remain poorly understood. Studies of terrain impacts by off-road vehicles in permafrost areas (Hok 1969, Rickard and Brown 1974) have concentrated on large vehicles weighing over 1000 kg used in conjunction with petroleum exploration and extraction (Table 1). These studies cannot be easily applied to ATV traffic because of differences in size and operation characteristics.

Anaktuvuk Pass, Alaska, located on the Continental Divide in the central Brooks Range (Fig. 2), is a village where the use of ATVs for summer subsistence hunting and fishing in several nearby mountain valleys has increased over the past ten years. This change has been necessitated by a number of factors (wage economy, loss of pack dogs, etc.) described by Hall et al. (1985). Travel by ATV in the vicinity of Anaktuvuk Pass village has resulted in passage over lands included in Gates of the Arctic National Park and Preserve. The National Park Service has established access easements through nonwilderness park lands for ATVs. Here there is a need to quantify the levels of disturbance or impacts on the terrain produced by this ATV traffic. This report describes the terrain disturbance on ATV trails in the Anaktuvuk Pass area in terms of microrelief, permafrost, soil, vegetation and visible changes.

BACKGROUND

Study area

Anaktuvuk Pass is located at an elevation of 670 m (2200 ft) on the Continental Divide, 120 km north of the Arctic Circle in the central Brooks Range, which forms an east–west mountain range across northern Alaska (Fig. 2). Here in the Endicott Mountains, glaciated U-shaped valleys at elevations of 600–900 m alternate with rugged mountain slopes and peaks reaching elevations of 1500–1800 m.

Numerous glacial and mass-wasting features in these valleys include kames, moraines, alluvial fans, talus, colluvial slopes, solifluction lobes, rock glaciers, rockfall chutes and debris cones. Most rocks are Paleozoic limestone, sandstones, shales and various grades of their metamorphic equivalents. Glacial moraine and drift deposits overlie most of this bedrock in the valleys.

The climate of the Anaktuvuk Pass area is generally continental, with long winters (Oct–May), short summers (June–September), low precipitation (less than 45 cm/yr) and persistent winds. The mean annual temperature is –10°C, with winter temperatures ranging from –30° to –12°C and summer temperatures ranging from 0° to 20°C (Brown and Berg 1980). The coldest month is December (–25°C). July has a mean temperature of 10.5°C. Thaw usually starts on May 18, and freeze starts September 16, so the thaw season is 121 days.*

The area is located in the zone of continuous permafrost. The upper slopes have deep active layers (1–2 m) and coarse-textured and freely drained soils, while the lower slopes and valley bottoms have thin active layers (0.5–1.0 m) and wet, fine-grained soils. Permafrost is, however, generally discontinuous beneath the flood plains of the larger streams (Brown and Berg 1980). Ground ice is more common in fine-grained deposits than in coarse-grained deposits. Since much of the Anaktuvuk Pass area is covered with coarse glacial materials, ground ice may not be extensive. Evidence of ground ice in the form of ice-wedge polygons is rare in the area except for some localized areas near river channels.

White spruce tree line occurs on the south slope of the Brooks Range at an elevation of 600–700 m, with trees extending up the John River to within 25–30 km of Anaktuvuk Pass. Because treeline is both latitudinally and altitudinally determined here, the vegetation of the entire study area can be considered "arctic-alpine tundra" (Cooper 1986).

In general, alpine tundra or dry tundra communities occupy better-drained mountain slopes, ridges, moraines, flood plains and other coarse-textured soils. Mountain avens (*Dryas octopetala* and *D. integrifolia*) is generally dominant throughout, growing in association with mosses, lichens, sedges, grasses, low herbs and prostrate shrubs, with a combined cover of less than 50%. At elevations above 1400 m, the mountain slopes are often barren except for lichens and a few flowering plants.

In the valley bottoms along the streams, taller flood-plain shrub vegetation often develops, with willows, low birch, grasses and herbs. Old flood-plain terraces with high moss and lichen cover are common along the larger streams.

Between the flood plain and the mountain slopes of most valleys, a broad range of wet, moist or dry vegetation types is common. On flat areas in the valley bottom and near small streams, wet tundra vegetation of sedges, willow and moss is common. On slightly better-drained ground, moist sedge tussock tundra occurs, with cottongrass tussocks, low shrubs, mosses and lichens. Nearer the valley sides, wet solifluction lobes with wet tundra vegetation are common.

*Personal communication with R. Haugen, CRREL.

Trail use

Over 160 km (100 miles) of ATV trail routes, used over the past ten years, have been identified by Anaktuvuk Pass residents (Hall et al. 1985). These trails reach into at least seven U-shaped glacial valleys or tributaries to the John and Anaktuvuk rivers (Fig. 2). The John River begins near Anaktuvuk Pass and flows south to the Koyukuk River. The Anaktuvuk River originates east of Anaktuvuk Pass and flows north to the Colville River in the Arctic Coastal Plain. These two major river valleys and their tributary stream valleys provide trail routes out from Anaktuvuk Pass to hunting and fishing areas 32–64 km (20–40 miles) from the village (Fig. 2).

The tributary stream valleys where trails are located (Fig. 2 and 3) include Kongumavik and Akmagolik creeks, which both flow into the Anaktuvuk River. Contact Creek, Giant Creek, Kollutarak Creek, Masu Creek and Ekokpuk Creek are tributaries to the John River. The Kollutarak Creek drainage is used as a route to Chandler Lake. These tributary stream valley trails are reached using four "access" trails out from the village (Fig. 2).

The trail system shown in Figure 2 has most likely been used for some time as a means of travel in these valleys. In early times, winter dogsled

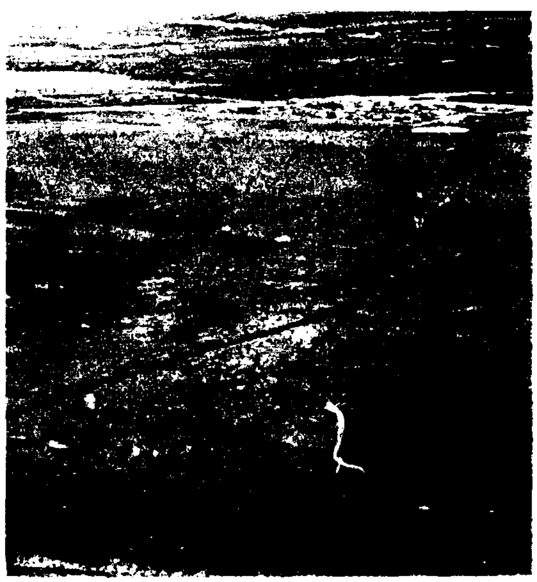


Figure 3. Aerial view of an ATV trail heading west from the village of Anaktuvuk Pass, visible in the background.

teams and summer walking with pack dogs was common. Beginning about 1960, snowmobiles were used on these trails, and finally all-terrain vehicle use became important for summer travel beginning about 1978 (Hall et al. 1985).

The great majority of the vehicles using these trails in 1985 and 1986 were the amphibious Argo six- or eight-wheel ATV manufactured by Ontario Drive and Gear in Ontario, Canada (Fig. 1). All six or eight wheels are driven by a chain drive over a fixed axle. In 1985 about 50 of these vehicles were owned by the 200–250 residents of Anaktuvuk Pass. Although the three- and four-wheel all-terrain cycles are common in Anaktuvuk Pass, these are used mainly within the village. The Argo weighs 400–600 kg, is 1.6 m wide with 20 cm of ground clearance, and has low-ground-pressure (0.1 kg/cm^2) tires (usually the Runamuck tire) with shallow cleats (Fig. 1). The Argo can carry two to six passengers or up to 540 kg. A single trip may consist of 30–60 km using one tank (30 L) of fuel (Table 1). The average traveling speed is probably 15–30 km/hr (Gerlach and Hall 1985).

These vehicles are operated during the summer (June–September) on the various trails. However, the trails in each valley are used at different times depending on water levels in the rivers and the location of caribou and sheep. Beginning in early or mid June, people start using the trails in Kongumavik, Akmagolik and Contact creeks (Fig. 2). Trails to the south, west and east of the village (Anaktuvuk River, Giant Creek, John River, Kollutarak River, Masu Creek and Ekokpuk Creek) are avoided until midsummer. From July on, these trails are used with increasing intensity into the fall.

The amount of traffic also varies with drainage. Based on Gerlach and Hall's (1985) survey, the Kongumavik–Akmagolik drainage receives the most traffic, followed (in order of decreasing use) by Anaktuvuk River, Kollutarak River, Giant Creek and Contact Creek. Masu Creek and Ekokpuk Creek receive little use.

METHODS

During June and August 1985 and June 1986, we made a general survey of ATV trail conditions in the Anaktuvuk Pass area. In 1985 we first conducted an aerial reconnaissance of the valleys to determine general trail visibility and our ability to locate sample sites. In each valley we then chose from one to seven trail sites that we would visit on the ground and measure soil, vegetation and microtopographic conditions. Several access trail sites near the village were also selected.

About 31 trail sites were visited and measured during 1985 and 1986. Sites were selected to represent 1) a range of terrain types, including wet, moist and dry tundra, 2) upper, middle and lower sections of each valley, and 3) a range of trail visibility conditions from not visible from the air to highly visible. During both years, trail users from Anaktuvuk Pass helped locate trail sites for sampling.

Table 2. Vehicle impact rating scheme. This system is modified from one developed by the Muskeg Research Institute (1970).

Vegetation

1 Undamaged; no discernible change.
2 Slight compression; leaves or stems temporarily bent or rearranged; vehicle passage barely perceptible.
3 Mosses, graminoids and other herbaceous species compressed and leaves flattened; shrubs stems becoming compressed.
4 Leaves or mosses and lichens torn or removed; woody shrub stems flattened, with some breakage and abrasion.
5 11–25% of original vegetation composition not discernible.
6 26–50% not discernible.
7 51–75% not discernible.
8 76–100% not discernible.

Soil

1 None exposed.
2 1–5% exposed.
3 6–10% exposed.
4 11–25% exposed.
5 26–50% exposed.
6 51–75% exposed.
7 76–90% exposed.
8 91–100% exposed.

Microrelief

1 No discernible change or depression of the surface.
2 Tracks evident but with less than half of track depressed 2.5 cm; slight compression of tussocks or hummocks.
3 Surface depression less than 2.5 cm over majority of track; slight to moderate compression of tussocks or hummocks.
4 Track depressed 2.5–5 cm; moderate tussock or hummock compression.
5 Track depressed 5–10 cm; moderate to severe tussock or hummock compression.
6 Track depressed 10–15 cm; severe tussock or hummock compression.
7 Track depressed 15–20 cm; severe compression or destruction of tussocks or hummocks.
8 Depressions or ruts greater than 20 cm deep; tussocks or hummocks completely flattened or destroyed.

At all trail sites, topographic position, vegetation type and trail visibility were measured. Trail visibility was evaluated using a scale of 0 = not visible, 1 = barely visible, 2 = visible and 3 = highly visible. To standardize and numerically rate the level of disturbance, we modified a rating scheme developed by the Muskeg Research Institute (1970) (Table 2) and applied in northern Canada (Radforth 1972) and Alaska (Felix and Jorgenson 1984).

At about half of the sites, we measured the trail surface and frozen layer profiles by driving steel rods into the ground on opposite sides of the trail. An elastic cord and meter tape were stretched between these rods, and the distance from the cord to the ground surface measured at 5-cm intervals; a steel probe was used to measure the distance from the cord to frozen ground at 10-cm intervals. In addition a quadrat frame (1 x 0.2 m) was located along this profile transect to sample vegetation in the tracks, in the center strip and in a control area to the side of the trail. Plant species were recorded and cover estimated.

At least five sites were sampled initially in June 1985 and then again in August 1985 and June 1986 to determine the rate of change due to traffic. Large orange paper crosses were used to mark these sites for later identification from the air.

RESULTS

In all of these valleys a single ATV trail of varying width and visibility follows the U-shaped valley bottom paralleling the river or creek at varying distances from the main channel (Fig. 4). Within a valley these trails traverse a variety of terrain conditions, including wet solifluction slopes and flat valley floors, moist gentle slopes and dry moraines, flood plains or old river terraces. Because of the glacial activity and the cutting of the river in these valleys, there is frequently an abrupt change from one type of substrate or terrain to another, and this creates abrupt changes in the visibility of ATV trails from the air (Fig. 5).

In large, broad valleys, such as along the Anaktuvuk River or Kollutarak Creek, the trail frequently drops down onto the active flood-plain gravels or onto older river terraces. In the narrow valleys, such as the Kongumavik and Contact creek valleys, the trail may traverse the valley sides (Fig. 4). Elevations of the ATV trails within these valleys range from 670 m at Anaktuvuk Pass up to 1050 m where they cross alpine slopes at the heads of some valleys.

Because of the close relationship between ATV trail conditions and the terrain–drainage type (Fig. 5), the 31 trail samples were grouped into

Figure 4. Aerial view of an ATV trail along a valley stream in the Anaktuvuk Pass area.

Figure 5. Aerial view of an ATV trail passing abruptly from poorly drained moist tundra to well-drained dry tundra.

wet, moist and dry tundra sites. The results of our study are discussed in terms of ATV impacts or trail conditions on these three terrain types. The amount of traffic is also important in determining impacts, but there was no way to quantify this variable here. For each of the three terrain types, the trails have produced measurable effects on soils and vegetation described below.

The ATV trails consist of one to many tracks. The majority of trails are 1.5–2.0 m wide (single track), and the widest are up to 100 m where multiple tracks parallel each other on wet valley bottoms. The mean width of all of these single-track trails is 1.82 m. Hence a 1-km length of trail affects about 0.18 hectare on the average.

Most trails have a distinct center strip and two tire depressions; typically a 1.8-m-wide trail would consist of two tracks each about 40–50 cm wide (averaging 47 cm) and a center strip about 50–90 cm wide (averaging 68 cm). Therefore, the ATV tracks themselves only comprise about 55–60% of the trail, with the center strip about 40–45% of the trail. The most heavily used access trails and trails where snowmobiles are used in early spring may have no center strip.

Dry tundra

Disturbance levels over dry tundra were low to moderate (Fig. 6, Table 3) with very little change in the relief or rutting due to the hardness of the substrate (Fig. 7). Dry tundra trails always consist of a single track since they do not become impassable. These sites were generally too rocky to measure thaw depths, and with the low ice content of these sites, the ATV traffic probably does not cause thawing.

On upland fell-fields and moraines and mountain slopes, the sparse vegetation includes low-

Table 3. Disturbance ratings for the 31 sites.

Location	*Vegetation*	*Soil*	*Microrelief*	*Total*	*Aerial visibility*
			Dry tundra		
Access south	2	2	1	5	.0
Anaktuvuk	2	2	1	5	1.0
Anaktuvuk	3	3	2	8	1.0
Anaktuvuk	4	3	2	9	2.0
Anaktuvuk	5	3	2	10	1.0
Giant	4	3	4	11	1.0
Kongumavik	6	4	2	12	3.0
Akmagolik	6	4	3	13	2.0
Anaktuvuk	5	5	3	13	2.0
Contact	6	4	3	13	2.0
Kongumavik	5	5	4	14	3.0
Access north	6	5	4	15	3.0
Kollutarak	8	5	3	16	3.0
			Moist tundra		
Masu	2	1	2	5	1.0
Giant	2	2	3	7	1.0
Kollutarak	3	2	2	7	1.5
Akmagolik	6	4	4	4	2.0
Kongumavik	7	7	6	20	3.0
Giant	8	7	6	21	3.0
Access south	7	7	7	21	3.0
Access west	8	8	8	24	3.0
Access northeast	8	8	8	24	3.0
			Wet tundra		
Akmagolik	3	2	5	10	1.0
Contact	4	4	5	13	1.0
Anaktuvuk	4	4	5	13	2.0
Kongumavik	4	6	7	17	3.0
Contact	7	5	6	18	3.0
Anaktuvuk	7	7	5	19	3.0
Contact	7	5	8	20	3.0
Anaktuvuk	7	6	7	20	3.0
Kongumavik	8	6	6	20	2.5

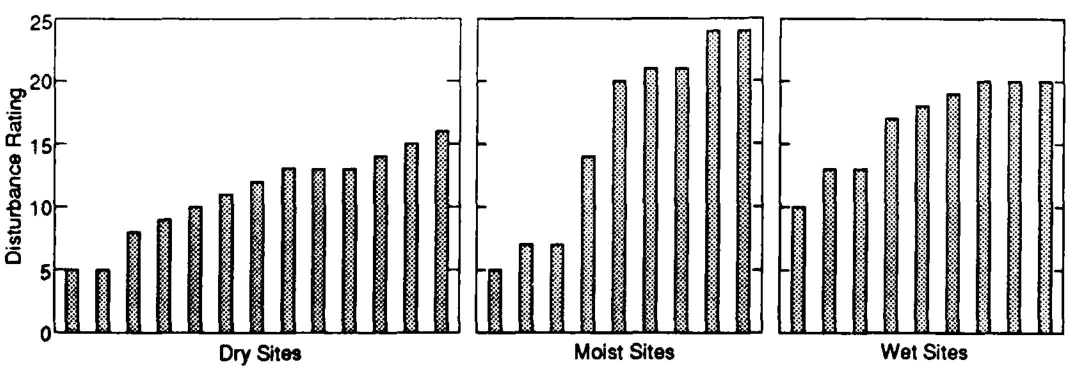


Figure 6. Terrain disturbance ratings for trail sites on dry, moist and wet tundra.

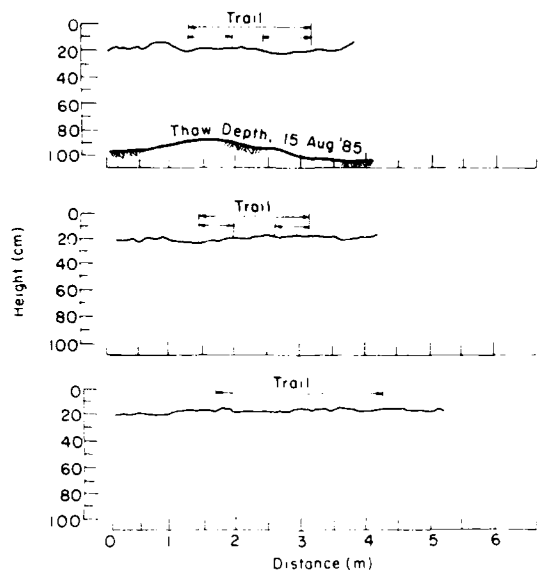


Figure 7. Surface profiles of three ATV trails over dry tundra.

growing shrub mats (*Dryas* sp.), sedges and lichens with frequent rock exposure. On such ATV trails, lichen cover was significantly reduced, but survival of shrub mats and sedges was high. Where there is a darker organic soil, removal of light-colored lichens may result in highly visible trails (Fig. 8). Other trails over very rocky dry tundra showed little or no increase in soil exposure and were barely visible.

On better-vegetated old river terraces with high moss cover and taller shrubs of birch or willow, terrain disturbance was generally low. The moss cover here is resistant to damage, but the taller shrubs are broken, and in dense shrub-covered flood plains, the shrub cover can be completely destroyed. Such trails may be highly visible from the air. The flowering of some flood-plain species (*Oxytropis borealis*) may also be disrupted by the traffic, increasing trail visibility (Fig. 8c).

Moist tundra

Terrain disturbance levels over moist tundra varies from low to high (Fig. 6, Table 3) depending on traffic levels. The highest levels were observed on access trails near the village, where there is increased traffic. Most trails with high terrain disturbance levels become impassable and therefore include a second or new trail or

a. Trail with a moderate level of disturbance.

b. Aerial view of an ATV trail over dry tundra. The trail is visible and has a moderate level of disturbance.

Figure 8. ATV trails over dry tundra

c. ATV trail over dry tundra on an old river terrace with a low disturbance rating. Note the suppression of flowering of Oxytropis borealis *in the tracks.*

e. Aerial view of the same dry tundra trail along the Kollutarak River. The trail is highly visible here.

Figure 8 (cont'd). ATV trails over dry tundra.

d. Moderate level of terrain disturbance over dry tundra trail on an older flood plain. Vegetation disturbance is high because of the loss of low birch shrubs.

track (Fig. 9a). Trail widths here may reach 3–8 m.

Cottongrass tussocks readily support the weight of an Argo and reduce damage to vegetation in the wet intertussock spaces (Fig. 9b). At these low-disturbance tussock–shrub tundra sites, ATV traffic has compressed tussocks 12–15 cm tall to approximately half their original height (Fig. 9c). Once the cottongrass tussocks are destroyed, the vegetation cover is drastically reduced, deep ruts develop, and disturbance levels are high.

At the sites with high disturbance levels, there is evidence of increased thaw beneath the trail (Fig. 10). The active layer in mid-August was 35 cm outside the trail (control) and 80 cm beneath the original surface under the abandoned section. Here there was some surface subsidence caused by melting ice beneath the trail. None of the moist tundra sites with low to moderate levels of disturbance showed increased thaw beneath the tracks.

At two moist tundra sites, we measured profiles initially in late June and then in mid-August (Fig. 10). At both sites, ATV traffic use during the 1.5 months between sample dates resulted in an increase in surface depression of 5–6 cm and in trail width of 40–50 cm.

a. High level of terrain disturbance on an ATV trail over moist tussock tundra.

c. Cottongrass (Eriophorum vaginatum) *tussock damage on an ATV trail showing compression and tearing of tillers.*

Figure 9 (cont'd).

b. Low level of terrain disturbance on an ATV trail over moist tundra.

Figure 9. ATV trails over moist tundra.

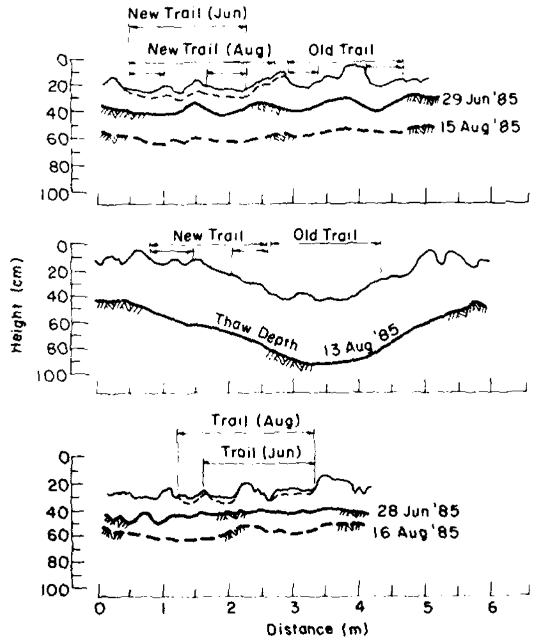
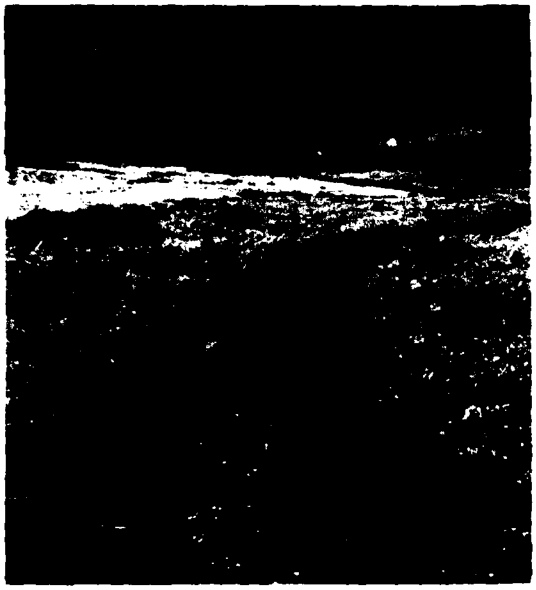


Figure 10. Profiles of surface and frozen layer topography on moist tundra ATV trails. The three profiles represent moderate, high and moderate levels of disturbance. The top and bottom profiles were sampled in June and resampled in August.



a. Site with moderate level of disturbance.

b. Wet tundra trail with multiple tracks.

Figure 11. ATV tracks over wet tundra.

The five moist tundra sites with high levels of terrain disturbance were all highly visible (Fig. 9a). The other trails were slightly visible on the ground and only barely perceptible from the air (Fig. 9b).

Wet tundra

Although wet tundra trails are highly visible because of the compression of the vegetation beneath the water surface (Fig. 11), actual terrain disturbance is often only moderate (Fig. 6, Table 3). However, unlike dry and moist tundra trails, none of the sample sites had low levels of disturbance. Because of the standing water in the tracks, it is frequently difficult to rate disturbance on wet tundra trails. Three of the nine wet tundra trail sites showed high levels of disturbance (Fig. 6). In most cases wet tundra areas are avoided by trail users, and drivers will move to a new trail before severe damage can occur. Therefore, trails over wet tundra often consist of several tracks depending on the wetness and traffic at the site. Over 10 sets of tracks on one wet meadow site produced a trail width of over 100 m (Fig. 11b).

Vegetation cover was generally lower in the tracks than in the adjacent controls, because of the compression of both live and dead sedge leaves beneath the standing water in the tracks.

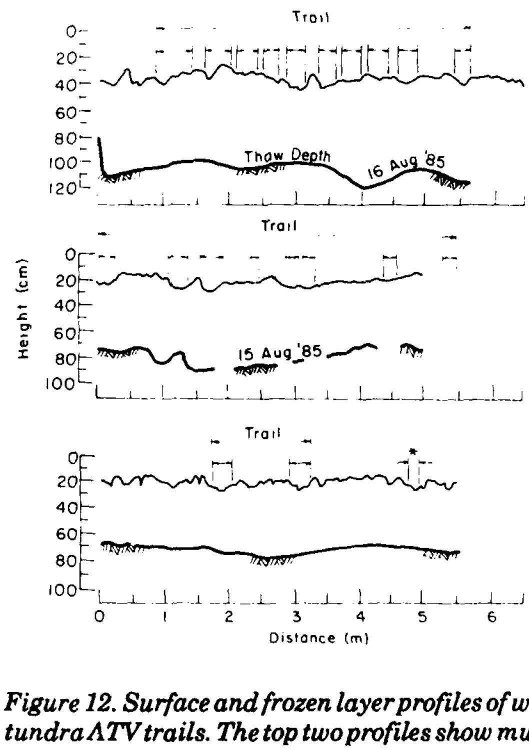


Figure 12. Surface and frozen layer profiles of wet tundra ATV trails. The top two profiles show multiple tracks, and the bottom shows a caribou trail (*) in addition to the ATV trail.

In some tracks, regrowth of these sedges results in greener strips than the adjacent meadow, where there are still standing dead leaves. Because wet meadow sites generally have few shrubs, little or no shrub damaged occurred.

There was no evidence of increased thaw beneath three trails over wet tundra, even where multiple ruts had developed (Fig. 12).

DISCUSSION AND CONCLUSIONS

Of the 31 trail samples, 8 were rated at a high level of disturbance (20–25), 16 showed moderate levels of disturbance (10–19), and 7 were rated at a low level (0–9) (Fig. 6). At five moist tundra trail sites and three wet tundra sites the terrain disturbance was high. None of the wet tundra trail sites had a low level of terrain disturbance because of the high surface depression produced by only one vehicle pass. In contrast, trails over moist tussock tundra support a relatively large number of passes with low–moderate disturbance levels until the tussocks break down. Racine and Ahlstrand (1985) showed that at least 100 passes of a six-wheel vehicle similar to the Argo were required to produce a high level of terrain disturbance over tussock tundra. Although wet tundra trails often consisted of multiple water-filled ruts, there was little evidence of vegetation destruction, thermokarst formation or increased subsurface thaw. Other studies generally show that wet tundra is more easily damaged than other terrain types by summer vehicle traffic (Walker et al. 1985). The same studies also suggest that wet tundra recovers more rapidly than other types (Ebersole 1985). No ATV trail over dry tundra received a high overall disturbance rating; however, vegetation disturbance to taller shrubs and lichens may be high.

There are insufficient samples to compare the levels of disturbance on trails in each of the seven valleys. However, our observations of the valley trails suggest the following ranking from highest to lowest levels of visibility: Kongumavik (highly visible), Contact (visible), Anaktuvuk (barely visible), Kollutarak (barely visible), Giant (barely visible), Masu (not visible) and Ekokpuk (not visible). This rating reflects the interaction between the intensity of use and the landscape characteristics (flood plain area, steepness, vegetation).

The highest levels of terrain disturbance on trails are located on the four access trails out of the village; the access trails to the west and north (to Contact and Kongumavik creeks, respectively) probably receive heavy use and are located in areas of poor drainage.

Traffic levels and seasonality of ATV use of the various valley trails, as described by Gerlach and Hall (1985), generally correlate with the observed levels of disturbance. Kongumavik and Contact creeks receive early spring use and are used throughout the remainder of the summer. The Anaktuvuk valley is used intensively from late July through September, but levels of disturbance are moderate to low. The Kollutarak Creek valley trails, although heavily used from late June through September for hunting and for reaching Chandler Lake, appeared to have low levels of disturbance. Finally, the Masu and Ekokpuk creek trails have not been used in recent years, although Gerlach and Hall (1985) mentioned that a group of about 20 people with four or five Argos visited the mouth of Masu Creek in July 1985. We observed no or very low levels of disturbance on trails in these two valleys.

The general disturbance level of ATV trails in the Anaktuvuk Pass area appears to be low relative to those surveyed farther south in Alaska, where a wide range of ATV types have highway access to trails. High levels of disturbance have been described on ATV trails in the Denali Highway area (Sparrow et al. 1978) and Nabesna area (Racine and Ahlstrand 1985). Permafrost damage by off-road vehicles is expected to be less in the Anaktuvuk Pass area because of the low occurrence of ground ice and the more stable permafrost conditions (because of lower temperatures) than in these more southern Alaska areas. In addition the trails in the Anaktuvuk Pass area are used mainly by one type of vehicle (Argos) with low surface pressure, rather than a broad range of off-road vehicles including four-wheel-drive trucks, Weasels and all-terrain cycles.

In the Anaktuvuk Pass area the ATV trails described here have natural analogs (Walker et al. 1987) in the form of linear trails resulting from the concentrated movement of caribou through the area (Fig. 13). These caribou trails are most striking wherever a migration or travel route is narrowed around the side of a lake or mountain (Bee and Hall 1956). Caribou trails tend to be diffuse and spread out in many parallel tracks about 1 m apart and can be confused with ATV trails, particularly from the air. The annual trampling by thousands of hooves may eventually remove vegetation, expose the soil, and produce depressions or ruts; near Chandler Lake we

Figure 13. Aerial view of multiple caribou tracks over dry tundra in the Chandler Lake area.

measured depressions up to 20 cm deep with a trail width of about 25 cm. The wheel tracks on the Argo trails are about the same width but are generally shallower. The similarity of caribou trails to those produced by ATVs suggests that this type of disturbance is not new to the tundra ecosystems of this area.

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